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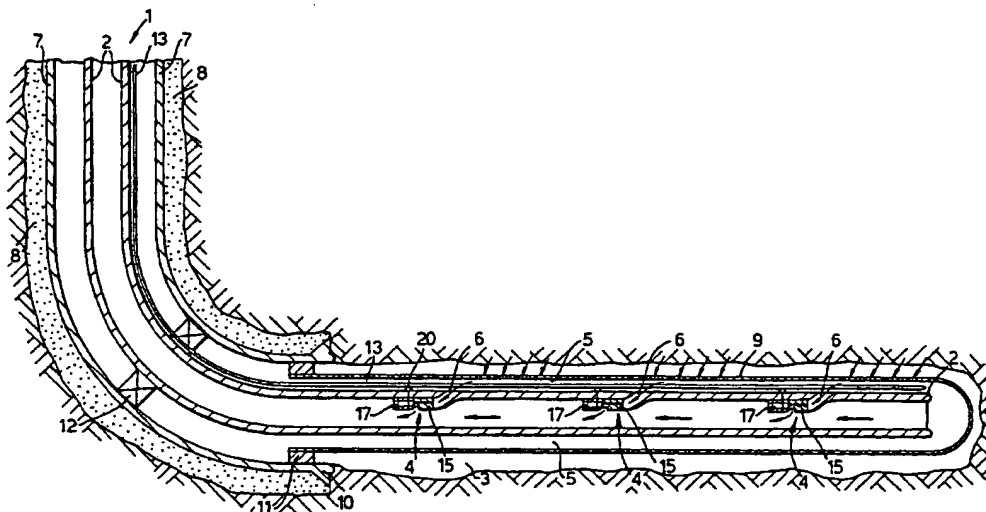
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **SYSTEM FOR ENHANCING FLUID FLOW IN A WELL**



(57) Abstract: A system for enhancing fluid flow into and through a hydrocarbon fluid production well comprising a series of flow boosters, such as electrically or hydraulically driven moineau-type pumps or centrifugal pumps or turbines, for controlling and/or boosting fluid flow from various regions of a drainhole section of the well into a production tubing within the well.

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## SYSTEM FOR ENHANCING FLUID FLOW IN A WELL

Background of the invention

The invention relates to a system for enhancing fluid flow into and through a hydrocarbon fluid production well.

5        Such a system is known from European patent specification 0558534 and US patent 5,447,201. The system known from these prior art references comprises a series of flow control devices, in the form of adjustable valves, for controlling fluid flow from various regions  
10       of a drainhole or reservoir inflow section of the well into a production tubing within the well.

      In the known system each valve throttles back production from a specific region of the drainhole section which will reduce the flux of fluids from the  
15       reservoir into that region. To compensate for the restriction of fluid flow into the well the known system is equipped with a flow booster which is installed in the production tubing downstream of the drainhole section of the well.

20       Disadvantages of the known system are that the downhole valves may get stuck as a result of corrosion, sand influx or deposition of salts, scale and that the combination of a series of valves and a flow booster in the well creates a large amount of wear prone components  
25       in the well and requires a complex assembly of electrical wiring to operate and control these components. Furthermore the valves can only be replaced after the flow booster in the production tubing has been removed so that replacement of valves requires a complex and costly  
30       workover operation wherein the flow booster and

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production tubing need to be removed to gain access to the valves.

European patent EP 0922835 discloses a multilateral well in which pumps are installed at the branchpoints to control the influx of the various branches into the main wellbore. The known pumps block the entrances of the branches such that maintenance or logging tools cannot be inserted into the branches and the entire production string and associated pump assemblies has to be removed from the well if maintenance or logging activities are required in one of the well branches.

US patent 5,881,814 discloses another non-bypassable multistage pump assembly in a well. US patents 3,741,298 and 5,404,943 disclose multiple pump assemblies in which the lowermost pump cannot be bypassed by logging or maintenance tools whereas the upper pump units are arranged adjacent to a by-pass conduit and are secured to the production tubing such that the entire tubing string has to be removed if the pumps need to be repaired or replaced.

The invention aims to overcome these disadvantages and to provide a flow booster system which does not obstruct entrance to the lowermost parts of the well and where the flow boosters can be removed or replaced individually without removing the production tubing or liner.

#### Summary of the invention

The system according to the invention comprises a series of flow boosters which control the inflow rate of fluid from various regions of a drainhole section of a well into a production tubing or liner within the well and which flow boosters are retrievably mounted in side pockets of said production tubing or liner.

Suitably the flow boosters comprise a series of electrically or hydraulically driven moineau-type

positive displacement pumps or rotary turbines which are mounted inside tubular mandrels that are retrievably mounted inside side pockets in a production liner or tubing.

5            Preferably each pump is equipped with sensors for measuring the flow rate and/or composition of fluids passing through the pump and the pump rate is adjustable automatically or manually in response to any significant deviation of the fluid rate and/or composition from a  
10           desired flow rate and/or composition.

          It is also preferred that the production tubing extends through the drainhole section and is surrounded by an annular inflow zone and the downhole pumps are distributed along the length of said inflow zone such  
15           that each flow booster draws fluid from the inflow zone and discharges fluid into the production tubing. Suitably one or more annular insulation packers are arranged in said annular inflow zone to create an annular inflow zone in which a plurality of hydraulically insulated drainhole  
20           regions are present and a plurality of flow boosters draw fluid from a plurality of said regions. Suitable annular insulation packers are inflatable rubber packers or annular bodies of cement which are injected into the annulus at locations halfway between a pair of adjacent  
25           pumps.

#### Description of preferred embodiment

A preferred embodiment of the system according to the present invention will be described by way of example with reference to the accompanying drawings, in which

30           Fig. 1 shows a schematic longitudinal sectional view of a hydrocarbon production well which is equipped with a system according to the present invention; and

          Fig. 2 shows at an enlarged scale one of the flow boosters of the system shown in Fig. 1.

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Referring now to Fig. 1 there is shown an oil production well 1 of which the production tubing 2 extends through a substantially horizontal drainhole section 3 and is equipped with three flow boosters 4 which pump fluid from various regions of an annular inflow region 5 through three longitudinally spaced orifices 6 in the wall of the production tubing 2.

The well 1 further comprises a well casing 7 which is cemented in place by an annular body of cement 8. A slotted production liner 9 is secured to the lower end of the casing, near the casing shoe 10 by means of a liner hanger 11.

The production tubing is retrievably mounted within the casing 7 and liner 9 by means of a series of packers 12.

An electrical, fibre optical and/or hydraulic power and signal transmission conduit 13 is strapped to the outer surface of the production tubing 2.

As shown in more detail in Fig. 2 each flow booster is an electrically driven moineau-type or centrifugal-type pump and the rotor 14 of each pump 15 is directly secured to the output shaft 16 of an asynchronous electrical motor 17 of which the rotor part comprises one or more permanent magnets and the stator part 18 comprises coiled electrical conduits 19 which generate in use a rotating electromagnetic field.

The coiled electrical conduits 19 are connected to the electrical power and signal transmission conduit 13 via one or more wet mateable induction electrical connectors 20.

Each pump 15 and motor 17 is mounted within a tubular mandrel 21 which is retrievably mounted within a side pocket 22 in the production tubing 2.

Each mandrel 21 is equipped with sensors (not shown) for measuring the flow rate and composition of fluids

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passing through the orifice 6 and pump 15 and the sensors are connected to a control unit which adjusts the rate of rotation of the motor in response to variations of the flow rate or composition from a desired reference flow rate and/or composition.

In many situations due to pressure drops in an elongate horizontal drainhole section influx of fluids tends to be larger at the heel than at the toe of that region.

In such case it is preferred that the pumprate of the flow booster 4 at the toe of the well 1 is larger than the pumprate of the flow booster 4 in the middle and that the pumprate of the flow booster 4 in the middle of the well is larger than the pumprate of the flow booster 4 at the heel of the well 1. Thus the series of flow boosters 4 counteract pressure drops in the drainhole section and thereby achieve more uniform drawdown over the whole length of the drainhole section, thereby increasing production from a given reservoir.

Each flow booster 4 is equipped with an e.g. flapper type, non-return valve (not shown) which prevents fluids to flow back from the production tubing 2 into the surrounding annulus 5 in case the pump would fail.

Each tubular mandrel 21 may have a kidney or oval shape to permit the use of a larger pump and motor and sensor and control unit within the mandrel 21.

The motor output torque and speed and pressure drop across each pump 15 may be measured as for an axial pump this is related to the density of the oil/gas/water fluid mixture and to the fluid viscosity.

The viscosity and density of the gas/oil/water mixture or emulsion can also be measured by carrying out surface tests at downhole pressure and temperature, the fluid sample having been mixed to simulate downhole conditions. Thus the fluid mixture being pumped by each

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pump 15 may be inferred from downhole data. The motor output torque may be calculated from its downhole back electromagnetic field (magnitude and phase) corrected for winding temperature.

5           If the well 1 is an oil well and the influx of gas is not desired the pumps 15 may be designed to stall or become less efficient an ingress of gas.

          The speed of revolution of the electric motors 17 may be varied to optimise the total flow of oil from the  
10       entire drainhole section 3. The pumps 13 may be turned to allow a selected amount of gas to be pumped into the production tubing 2 to create a gas lift in the vertical upper part of the production tubing 2.

          The intelligence and control system may be downhole  
15       or at surface or distributed.

          The electrical conduit 13 can be a single conduit or a bundle of conduits or contain a releasable connections downhole in a hanger 11 and instrumentation connector.

          If one or more pumps 15 are driven by hydraulic  
20       motors or are formed by jet pumps then the motor or pump may be powered by injection of treating chemicals such as an emulsifier, H<sub>2</sub>S scavenger, corrosion inhibitor, descaler, Shellswim (a Shell trade mark) or a mixture of these fluids into the pump 15 or motor. Hydraulic  
25       conduits extending between the wellhead and the downhole pump and motor assemblies may also be used to inject lubricating oil into the pump and motor bearing assemblies.

          The pumprates of the pumps 15 may be cyclically  
30       varied such that the point of maximum draw-down of oil into the production tubing 2 is continuously moved up and down between the lower and upper end of the inflow region. Such cyclic variation of the influx into the well reduces the risk of water or gas coning during  
35       production.

C L A I M S

1. A system for enhancing fluid flow into and through a hydrocarbon fluid production well, the system comprising a series of flow control devices for controlling fluid flow from various regions of a drainhole or reservoir inflow section of the well into a production tubing with the well, wherein the series of flow control devices are formed by a series of flow boosters which are retrievably mounted in side pockets of a production tubing or liner.
2. The system of claim 1, wherein the production tubing or liner extends through the drainhole section and is surrounded by an annular inflow zone and the downhole pumps are distributed along the length of said inflow zone such that each flow booster draws fluid from the annular inflow zone and discharges fluid into the production tubing or liner.
3. The system of claim 2, wherein one or more annular insulation packers are arranged in said annular inflow zone to create an annular inflow zone in which a plurality of hydraulically insulated drainhole regions are present and a plurality of flow boosters draw fluid from a plurality of said regions.
4. The system of claim 1, wherein the flow boosters are positive displacement pumps or rotary turbines that are driven by electrical or hydraulic motors.
5. The system of claim 4, wherein the flow boosters are moineau-type positive displacement pumps of which the rotor is directly coupled to the output shaft of an asynchronous electrical motor having a rotor part comprising one or more permanent magnets.
6. The system of claim 4 or 5, wherein the flow booster and motor are located within a tubular mandrel which is



retrievably mounted in a side pocket of a production liner or tubing and the motor is connected to an electrical conductor passing along said liner or tubing via one or more wet mateable electrical connectors.

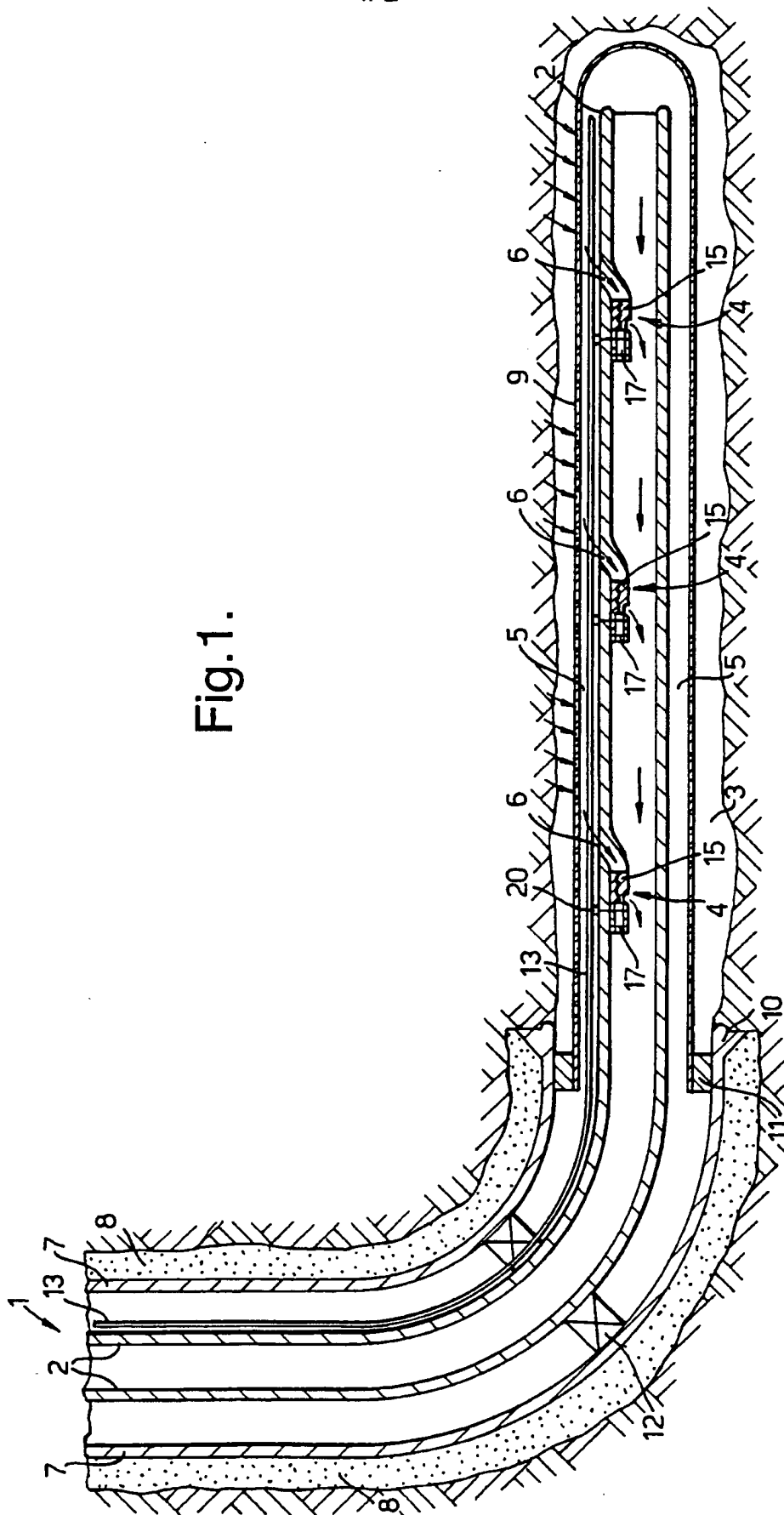
5 7. The system of claim 6 wherein pressure, temperature and/or fluid composition measurement sensors are mounted inside each mandrel and are connected to a flowrate control system of each flow booster such that the  
10 pumprate of a flow booster is restricted in case the measured flowrate is significantly larger than that of one or more other flow boosters or if the produced fluids comprise a significant amount of water or sand or another undesired fluid, such as natural gas if the well is an oil well.

15 8. The system of claim 1, wherein the flow boosters are jet pumps or gaslift assemblies.

9. A method of operating the system of claim 1, wherein the flow boosters are in use controlled such that  
20 pumprate of each booster cyclically varies between a maximum and minimum value and the pumprate variations of the various flow boosters are out of phase relative to each other.

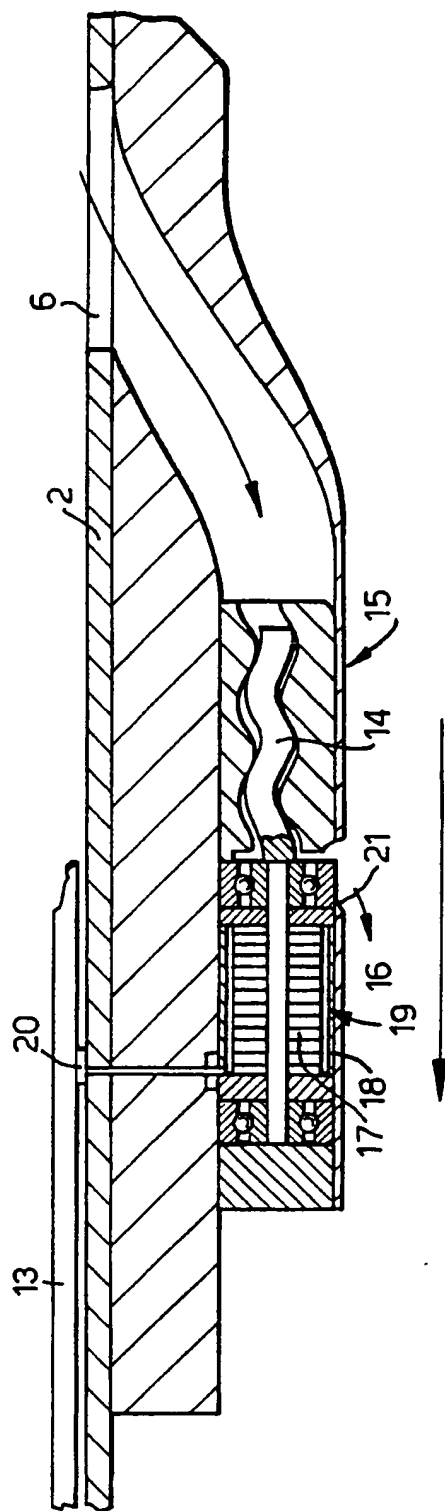
10. The method of claim 9, wherein the pumprates of the various flow boosters are cyclically varied such that the  
25 point of maximum influx into the inflow section of the well is cyclically moved between a lower end and an upper end of said inflow section.

Fig.1.



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Fig.2.



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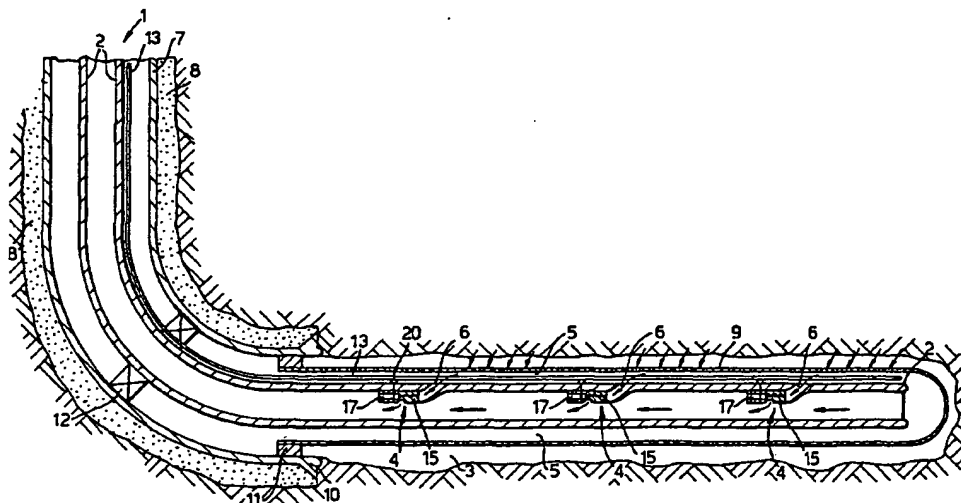
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ning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM FOR ENHANCING FLUID FLOW IN A WELL



(57) Abstract: A system for enhancing fluid flow into and through a hydrocarbon fluid production well (1) comprising a series of flow boosters (4), such as electrically or hydraulically driven moineau-type pumps or centrifugal pumps or turbines, for controlling and/or boosting fluid flow from various regions of a drainhole section of the well into a production tubing (2) within the well.



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# INTERNATIONAL SEARCH REPORT

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## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B43/12 E21B43/14 E21B47/00 E21B49/08 F04D13/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B F04D F04F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 223 109 A (CUMMINGS) 14 December 1965 (1965-12-14) column 1, line 12 - line 36 ---	1,8
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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# INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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# INTERNATIONAL SEARCH REPORT

Int .ional Application No  
PCT/EP 00/09184

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4 413 958 A (WEBB) 8 November 1983 (1983-11-08) abstract -----	1

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/EP 00/09184

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1 - 3, 8

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.



## INTERNATIONAL SEARCH REPORT

International Application No. PCT/EP 00/09184

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-3, 8

System for enhancing fluid flow in a well, using retrievable boosters which are distributed along the length of the inflow zone.

2. Claims: 4-7

System for enhancing fluid flow in a well, using retrievable boosters which are positive displacement pumps or rotary turbines.

3. Claims: 9, 10

System for enhancing fluid flow in a well, using retrievable boosters with pump rates which are cyclically varied.

# INTERNATIONAL SEARCH REPORT

information on patent family members

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Information on patent family members

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